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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

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SUBJECT—

TITLE

EXPERIMENTS WITH PENETRATING SPRAYS
CONDUCTED IN LODGEPOLE AND
WHITEBARK PINE IN 1940

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June 3, 1941

U.S. GOVERNMENT PRINTING OFFICE 5—9742

INDEX NO.—

EXPERIMENTS WITH PENETRATING SPRAYS CONDUCTED IN LODGEPOLE AND WHITEBARK PINE IN 1940

INTRODUCTION

Tests with penetrating sprays in 1940 against the mountain pine beetle have been divided in this report into three general groups:

(1) Tests of noncommercial formulae in lodgepole pine,

(2) Tests of noncommercial formulae in whitebark pine,

(3) Tests of Dow Chemical Company formulae as authorized by the Forest Insect Division.

The tests of the sprays from the Dow Chemical Company were made in both lodgepole and whitebark pine, a preliminary report of which has already been submitted. In this report the data and discussion are more detailed, permitting those who may be interested to make a more thorough study of method and results.

Tests of both non-commercial and Dow chemicals were conducted at Grand Teton Park in lodgepole pine and on the slopes of Mt. Washburn in Yellowstone Park in whitebark pine.

MATERIALS AND METHODS

Material used consisted of infested logs from trees and of standing trees. Following the examination of a six-inch strip or a standard-sized sample at the end of each log section, to determine the amount of brood, the remainder of the log was sprayed with the formula to be tested. Where trees were used to supplement data from sections, one-half of their circumference was sprayed to about five feet. Brood counts on the unsprayed side were deferred until similar counts were made on the sprayed area, thus permitting a direct measure of the

effectiveness of the control. Spray effectiveness was tested against various stages of development, where time and material permitted. This was done not only for the purpose of determining the resistance of the insect in these various stages but also to measure lethal effect under the varying bark conditions. It has been recognised that control of brood under green or wet bark is a much more difficult problem than under dry or nearly dry bark. Temperature and exposure to sunlight also vary in amount, and influence at least the speed and possibly the ultimate effectiveness of the sprays. In these experiments, the sprayed log sections were shaded to prevent exposure to sunlight. None of the sprayed areas of trees were shaded. We feel justified in believing that, with the elimination of the factor of sunlight, the data presented from the log sections are a conservative estimate of the effectiveness of the formulae.

TESTS OF NONCOMMERCIAL FORMULAE IN LODGEPOLE PINE

In July of 1940, testing of the control properties of various penetrating sprays, which has been in progress for a number of years at Grand Teton Park, was continued. The material on which the tests were made consisted of 30-inch sections of infested logs. Except that they were shaded to prevent possible sun-killing of brood, the log sections were arranged so as to closely duplicate the environment of nearby infested trees.

The success obtained in previous tests by the use of Diesel oil and a saturated solution of naphthalene in orthodichlorobenzene prompted their continuance with smaller amounts of the latter in Diesel

oil. In addition other chemicals were tested in the search for still cheaper and more effective sprays.

EXPERIMENTS

Formula 1

Saturated solution of naphthalene flakes in orthodichlorobenzene at 50° F. (3 lb. per gallon)....1 part

Diesel oil .....6 parts

The sections sprayed with Formula 1 yielded as good results as have been secured with the 4 parts Diesel oil to 1 part of the saturated solution. The data are shown in table 1.

Table 1 - Mountain pine beetle infested lodgepole pine treated with formula 1 (1) - Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating (2)								Surviving brood one month after treating (3)							
	Lar.	Pup.	P.A.	NAPH	Total	Sq. ft. of area examined	No. per sq. ft.		Lar.	Pup.	P.A.	NAPH	Total	Sq. ft. of area examined	No. per sq. ft.	
14.2	5	4	137	--	146	3.7	39.5		--	--	--	1	1	3.7	.27	
14.5	--	2	35	--	37	3.8	9.7		--	--	--	--	--	3.8	--	
12.2	7	5	51	--	63	3.2	19.7		--	--	--	--	--	3.2	--	
12.1	--	--	63	--	63	3.1	20.3		--	--	--	--	--	3.1	--	
14.4	1	2	28	--	31	3.7	8.4		--	--	--	2	2	3.7	.54	
13.5	13	13	314	--	340	17.5	19.4		--	--	--	3	3	17.5	.17	

Percent reduction in brood 99.

Brood in five check logs (4)

	At time treated sections were sprayed								At time treated sections were examined							
12.1	64	7	624	--	695	14.3	48.6		--	3	11	293	307	17.5	17.5	

Percent reduction in brood in the above check logs 64

(1) Saturated solution of naphthalene in orthodichlorobenzene at 50° F. (3 lb. per gallon) .... 1 part
Diesel oil ..... 6 parts

(2) July 4, 1940

(3) August 5, 1940

(4) Individual log data in table 11

In spite of the wide variation in the number of brood per square foot of surface, we find there are ample data on which to base a definite conclusion as to the effectiveness of the spray used. The five logs constituted five samples containing a total of 340 insects under the 17.5 square feet of bark examined. The average was 19.4 insects per square foot. When an equal treated area was examined one month later it showed only three surviving insects.

The excellent control secured with the lower concentration of the lethal material permits reducing the cost of the spray from about 22.5¢ per gallon at present costs to about 19¢, without sacrificing any effectiveness. Prices upon which the above estimates were based are Diesel oil 10¢ per gallon, orthodichlorobenzene 70¢ per gallon, and naphthalene flakes 7¢ per pound.

Formula 2

Saturated solution of naphthalene in ortho-dichlorobenzene at 80° F. (3 lb. per gallon) ..... 1 part

Diesel oil ..... 9 parts

A further reduction to 9 parts of oil to 1 part of the solution gave somewhat variable results, reductions in living brood per unit of area ranging from 79 to 100 percent. Eliminating the data of the third log section, which are statistically beyond the acceptable limits of variation, decreases the reduction obtained from 92 to 86 percent. The latter percent almost certainly indicates that a definite difference exists in the effectiveness of Formulae 1 and 2 as presented in tables 1 and 2. However, it is believed that if these sections could have been treated earlier in the season, thus permitting a longer exposure to the effects of the chemical, a much higher mortality would have resulted. The data for sections treated with Formula 2 are shown in table 2.

Table 2 - Mountain pine beetle infested lodgepole pine treated with formula 2 (1) - Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating (2)					Sq. ft. of area examined	No. per sq. ft.	Surviving brood one month after treating (3)					Sq. ft. of area examined	No. per sq. ft.
	Lar.	Pup.	N.A.	NAEH	Total			Lar.	Pup.	N.A.	NAEH	Total		
10.9	—	—	35	—	35	1.3	26.9	—	—	1	13	14	2.9	4.8
12.2	4	3	23	—	30	3.2	9.4	—	—	—	—	—	3.2	—
11.0	8	9	206	—	223	2.6	85.8	—	—	1	3	4	2.8	1.4
13.7	1	1	23	—	25	3.6	6.9	—	—	—	—	—	3.6	—
14.7	—	2	31	—	33	3.8	8.7	—	—	—	7	7	3.8	1.8
13.8	3	2	61	—	66	3.6	18.3	—	—	—	12	12	3.6	3.3
11.8	4	1	25	—	30	3.1	9.7	—	—	—	—	—	3.1	—
Totals and averages:	20	16	404		442	21.2	20.9	—	—	2	35	37	23.0	1.6
Without 3rd section	12	9	198	—	219	18.6	11.8	—	—	1	32	33	20.2	1.6

Percent reduction in brood 92 - (exclusive of 3rd section) - 86

Brood in 5 check logs (4)

	At time treated sections were sprayed							At time treated sections were examined						
12.1	64	7	624	—	695	14.3	48.6	—	3	11	293	307	17.5	17.5

(1) Saturated solution of naphthalene in orthodichlorobenzene at 50° F. (3 lb. per gallon) ..... 1 part
Diesel oil ..... 9 parts

(2) July 4, 1940

(3) August 5, 1940

(4) Individual log data in table 11

If a longer exposure to Formula 2 should not give satisfactory control, the excellent results obtained with Formula 1 and less effective control with Formula 2 indicate the possibilities of acceptable results being secured with concentrations between the two. Tests with 7 and 8 parts of oil are suggested as well as a repetition of 6 and 9 to test consistency of results.

Formula 3

Saturated solution of naphthalene in ortho-dichlorobenzene at 50° F. (3 lb. per gallon) .... 1 part

Diesel oil ..... 9 parts

Santomerse D (by weight) ..... 1 percent

A third formula, differing only from the second in the addition of one percent by weight of Santomerse D, a wetting agent, gave almost as effective control as Formula 1. In addition control was consistently good, being in no case less than 94 percent for any section treated. The results indicate the wetting agent had increased the effectiveness of the spray, thus permitting a reduction in the amount of lethal material. However, because of inconsistent results in previous tests with wetting agents it is felt that further experimenting with this formula should be done before recommending it. The data are presented in table 3.

Table 3 - Mountain pine beetle infested lodgepole pine treated with formula 3 (1) - Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating					Sq. ft. of area examined	No. per sq. ft.	Surviving brood one month after treating					Sq. ft. of area examined	No. per sq. ft.
	Lar.	Pup.	N.A.	NAHH	Total			Lar.	Pup.	N.A.	NAHH	Total		
12.0	4	2	44	—	50	3.1	16.1	—	—	—	—	—	3.1	—
12.1	3	4	51	—	58	3.2	18.1	—	—	—	3	3	3.2	.94
10.4	3	7	77	—	87	1.4	62.1	—	—	—	—	—	2.7	—
13.6	1	—	44	—	45	3.6	12.5	—	—	—	2	2	3.6	.56
17.3	36	3	14	—	53	4.5	11.8	—	—	—	2	2	4.5	.44
13.6	1	1	49	—	51	3.6	14.2	—	—	—	3	3	3.6	.83
	48	17	279		344	19.4	17.7	—	—	—	10	10	20.7	.48

Percent reduction in brood 97.3
Percent reduction in brood without log 3 96.1

Brood in 5 check logs (2)

At time treated sections were sprayed							At time treated sections were examined						
64	7	624	—	695	14.3	48.6	—	3	11	293	307	17.5	17.5

(1) Saturated solution of naphthalene in orthodichlorobenzene at 50° F. (3 lb. per gallon) ..... 1 part
Diesel oil ..... 9 parts
Santomerse D (1% by weight)

(2) Individual log data in table 11

Tests of pentachlorphenol in which 2 percent by weight of that chemical was dissolved in 98 percent Diesel oil and then sprayed on mountain-pine-beetle-infested lodgepole pine logs gave no apparent control. Examinations of brood before and seven weeks after spraying revealed only a 57 percent reduction in brood and a survival averaging at least 15 insects per square foot. The data from the four sections examined are given in table 4.

Table 4 - Mountain pine beetle infested ledgepole pine treated with formula M-1 (1) - Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating					Sq. ft. of area examined	No. per sq. ft.	Surviving brood one month after treating					Sq. ft. of area examined	No. per sq. ft.
	Lar.	Pup.	N.A.	NAEH	Total			Lar.	Pup.	N.A.	NAEH	Total		
14.3	5	1	27	—	33	3.7	8.9	—	—	1	10	11	3.7	3.0
14.2	33	21	49	—	103	3.7	27.9	—	—	—	30	30	3.7	8.1
13.1	12	2	192	—	206	3.4	60.6	—	—	9	92	101	3.4	29.7
12.6	4	—	148	—	152	3.3	46.1	—	—	5	66	71	3.3	21.5
	54	24	416	—	494	14.1	35.1	—	—	15	198	213	14.1	15.1

Percent reduction in brood 57

Brood in 5 check logs (2)

	At time treated sections were sprayed							At time treated sections were examined						
12.1	64	7	624	—	695	14.3	48.6		3	11	293	307	17.5	17.5

(1) Diesel oil .....98% (by weight)
Pentachlorphenol ..... 2% " "

(2) Individual log data in table 11.

Formula N-2

Pentachlorphenol (by weight) ..... 3 percent
Diesel oil (by weight) ..... 97 percent

An increase of the pentachlorphenol to 3 percent by weight combined with 97 percent Diesel oil, when sprayed on the infested sections, gave an indicated decrease in brood of only 26 percent, which is less than the normal mortality noted in the check sections. However, the data include one section which shows a decidedly abnormal departure from the other data, so much so that its elimination is statistically justified. Without that section the reduction is 57.5 percent, practically the same as for Formula N-1 and still equally unsatisfactory. The data are presented in table 5.

Table 5 - Mountain pine beetle infested lodgepole pine treated with formula N-2 (1) in Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating					Sq. ft. of area examined	No. per sq. ft.	Surviving brood one month after treating					Sq. ft. of area examined	No. per sq. ft.
	Lar.	Pup.	W.A.	WAEH	Total			Lar.	Pup.	W.A.	WAEH	Total		
11.7	—	—	12	—	12	1.5	8.0	—	—	—	13	13	3.1	4.2
14.0	4	3	82	—	89	2.9	30.7	—	—	—	215	215	2.9	74.1
13.9	—	1	53	—	54	1.8	30.0	—	—	2	32	34	3.6	9.4
12.7	5	—	164	—	169	3.3	51.2	—	—	2	59	61	3.3	18.5
11.6	3	3	95	—	101	3.0	33.7	—	—	—	76	76	3.0	25.3
10.7	8	—	27	—	35	2.8	12.5	—	—	—	17	17	2.8	6.1
	20	7	433	—	460	15.3	30.1	—	—	4	412	416	18.7	22.2

Without second section ..... 29.9 ..... 12.7
Percent reduction in brood 26
" " " " without second section 57.5

Brood in 5 check logs (2)

	At time treated sections were sprayed							At time treated sections were examined						
12.1	64	7	624	—	695	14.3	48.6	—	3	11	293	307	17.5	17.5

(1) Diesel oil .....97% (by weight)
Pentachlorphenol..... 3% " "

(2) Individual log data in table 11.

Formula N-3

Pentachlorphenol (by weight) ..... ¼ percent
Diesel oil (by weight) ..... 96 percent

A still further increase in the pentachlorphenol to ¼ percent gave indications of some control effectiveness. The average reduction in brood, however, was only 75.5 percent and the survival per square foot too high. The data are presented in table 6.

Table 6 - Mountain pine beetle infested lodgepole pine treated with formula M-3 (1) - Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating: Lar.	Pup.	M.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	Surviving brood one month after treating: Lar.	Pup.	M.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.
13.2	3	2	61	—	66	3.5	18.9	—	—	—	24	24	3.5	6.9
12.6	20	8	371	—	399	3.3	120.9	—	—	—	90	90	3.3	27.3
11.5	3	—	19	—	22	1.5	14.7	—	—	—	27	27	3.0	9.0
13.3	1	—	32	—	33	1.7	19.4	—	—	—	10	10	3.6	2.9
Totals and averages:	27	10	483	—	520	10.0	52.0	—	—	—	151	151	13.3	11.4

Percent reduction in brood 78

Brood in 5 check logs (2)

	At time treated sections were sprayed							At time treated sections were examined						
12.1	64	7	624	—	695	14.3	48.6	—	3	11	293	307	17.5	17.5

(1) Diesel oil ..... 96% (by weight)
Pentachlorphenol ..... 4% " "

(2) Individual log data in table 11.

Formula N-4

Pentachlorphenol (by weight) ..... 6 percent
Diesel oil (by weight) ..... 94 percent

The highest concentration of pentachlorphenol in the oil carrier, 6 percent by weight to 94 percent by weight of the Diesel oil, failed to produce satisfactory control. It seems apparent that this chemical in the above mixture is not effective against the mountain pine beetle in lodgepole, judging from the results secured in 1940. Table 7 contains the data concerning this formula.

Table 7 - Mountain pine beetle infested lodgepole pine treated with formula E-4 (1) - Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating							Surviving brood one month after treating						
	Lar.	Pup.	M.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	Lar.	Pup.	M.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.
13.4	3	—	43	—	46	3.5	13.1	—	—	1	12	13	3.5	3.7
12.2	9	1	167	—	177	3.2	55.3	—	—	—	83	83	3.2	25.9
12.3	1	—	18	—	19	3.2	5.9	—	—	—	—	—	3.2	—
11.7	2	1	14	—	17	1.5	11.3	—	—	—	3	3	3.1	.9
13.7	64	33	174	—	271	3.6	75.3	—	—	—	78	78	3.6	21.7
12.7	1	4	51	—	56	3.3	17.0	—	—	—	10	10	3.3	3.0
14.3	6	2	63	—	71	3.7	19.2	—	—	—	27	27	6.2	4.3
	86	41	530	—	657	22.0	29.9	—	—	1	213	214	26.1	8.2

Percent reduction in brood 72.6

Brood in 5 check logs (2)

At time treated sections were sprayed							At time treated sections were examined						
64	7	624	—	695	14.3	48.6	—	3	11	293	307	17.5	17.5

(1) Diesel oil ..... 94% (by weight)
Pentachlorphenol ..... 6% " "

(2) Individual log data in table 11.

Formula J-1

Dichlorethyl ether	1 part
Diesel oil	8 parts

In 1939 tests with four parts of Diesel oil to one of dichlorethyl ether gave excellent results. In 1940, although the formula was reduced to 8 parts of Diesel oil to 1 of dichlorethyl ether, the results obtained were still excellent, which indicates that it may be possible to even further reduce the amount of the dichlorethyl ether and secure satisfactory control. The data secured in the experiment conducted in 1940 are presented in table 8.

Table 8 - Mountain pine beetle infested lodgepole pine treated with formula J-1 (1) - Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating							Surviving brood one month after treating						
	Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.
12.8	19	5	63	—	87	3.4	25.6	—	—	—	—	—	3.4	—
12.3	—	2	76	—	78	3.2	24.4	—	—	—	—	—	3.2	—
12.0	2	3	60	—	65	3.1	21.0	—	—	—	—	—	3.1	—
11.9	2	1	29	—	32	3.1	9.7	—	—	—	—	—	3.1	—
9.6	15	16	119	—	150	2.6	57.7	—	—	—	1	1	2.6	.38
9.4	5	4	188	—	197	2.5	78.8	—	—	—	—	—	2.5	—
9.1	4	6	187	—	197	2.4	82.1	—	—	—	2	2	2.4	.83
	47	37	722	—	806	20.3	39.7				3	3	20.3	.15

Percent reduction in brood 99.6

Brood in 5 check logs (2)

	At time treated sections were sprayed							At time treated sections were examined						
12.1	64	7	624	—	695	14.3	48.6	—	3	11	293	307	17.5	17.5

(1) Dichlorethyl ether ..... 1 part (by volume)
Diesel oil ..... 8 parts " "

(2) Individual log data in table 11.

Further tests should be made with decreased concentrations of the more lethal ingredient, dichlorethyl ether.

Formula R-1

Orthonitrodiphenol	1 part
Diesel oil	3 parts

A spray comprising 1 part of orthonitrodiphenol to 3 parts of Diesel oil gave very good results. A light survival occurred and a small amount of living brood was still present in one leg section at the time of examination, but their unhealthy appearance indicated their probable death. As these unhealthy survivors made up about 40 percent of the total survival, their death would lower the survival to a very small figure. It is also believed still further mortality might have occurred if the treating could have been done about June 15. For the above reasons this formula should be given further tests at the same and lower concentrations of the orthonitrodiphenol. The data secured are presented in table 9.

Table 9 - Mountain pine beetle infested lodgepole pine treated with formula R-1 (1) - Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating					Sq. ft. of area examined	No. per sq. ft.	Surviving brood one month after treating					Sq. ft. of area examined	No. per sq. ft.
	Lar.	Pup.	N.A.	NAEH	Total			Lar.	Pup.	N.A.	NAEH	Total		
8.9	2	5	178	—	185	2.3	80.5	—	—	—	7	7	2.3	3.0
8.9	—	2	94	—	96	2.3	41.7	—	—	—	—	—	2.3	—
14.3	50	11	55	—	116	3.7	31.4	3	3	4	2	12	3.7	3.2
13.6	7	5	69	—	81	3.6	22.5	—	—	—	2	2	3.6	.6
13.4	3	4	63	—	70	3.5	20.0	—	—	—	—	—	3.5	—
13.1	7	4	45	—	56	3.4	16.5	—	—	—	3	3	3.4	.9
	69	31	504	—	604	18.8	32.1	3	3	4	14	24	18.8	1.3

Percent reduction in brood 96

Brood in 5 check logs (2)

	At time treated sections were sprayed							At time treated sections were examined						
12.1	64	7	624	—	695	14.3	48.6	—	3	11	293	307	17.5	17.5

(1) Orthonitrodiphenol ..... 1 part (by weight)
Diesel oil ..... 3 parts " "

(2) Individual log data in table 11.

Formula X-1

Saturated solution of naphthalene in xylene (3 lb. per gallon) .....1 part

Diesel oil .....3 parts

Tests with the above mixture were not made until July 20, by which time emergence of new adults had begun. Counts were made of emergence holes immediately before treating but, as the bark could not be removed without destroying the experiment, no differentiation between parent- and new-adult emergence holes could be made. When extensive examinations were made on August 11 it was found that emergence holes averaged 1.7 per square foot. The areas intensively examined on July 20 showed an average of about one new-adult emergence hole per square foot. If the difference in the data may be considered as indicative, new-adult emergence after treating averaged only .7 insect per square foot, which would be excellent control.

Table 10 - Mountain pine beetle infested lodgepole pine treated with formula X-1 (1) - Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating								Surviving brood one month after treating							
	Par.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.		Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	
13.2	—	1	44	—	45	3.5	12.9		—	—	—	1	1	3.5		
15.3	27	4	79	10	120	4.0	30.0		—	—	—	1	1	4.0		
14.2	—	—	57	6	63	3.7	17.0		—	—	—	9	9	3.7	2.4	
13.7	—	—	51	7	58	3.6	16.1		—	—	—	—	—	3.6		
13.8	3	5	39	—	47	3.6	13.1		—	—	—	20	20	3.6	5.6	
13.1	1	—	31	2	34	3.4	10.0		—	—	—	—	—	3.4		
12.7	—	—	16	—	16	3.3	4.8		—	—	—	1	1	3.3	.3	
	31	10	317	25	383	25.1	15.3		—	—	—	30	30	25.1	1.7	(2)

Percent reduction in brood (less an average of 1.0 insect per square foot from both examination averages) = 95

Brood in 5 check logs (3)

	At time other treated sections were sprayed								At time treated sections were examined							
12.1	64	7	624	—	695	14.3	48.6		—	3	11	293	307	17.5	17.5	

(1) Saturated solution of naphthalene in xylene (3 lb. per gallon) ..... 1 part
Diesel oil ..... 5 parts

(2) Includes only last five sections

(3) Individual log data in table 11

Check Sections

A study of five sections of trees examined at the time the treated sections were sprayed, and again at the same time that the treated sections were examined, revealed a 64 percent decrease in brood. This may be considered the normal reduction in brood over that period of time. Considerable variability in brood numbers is indicated in the data from the check trees which are given in table 11.

Table 11 - Mountain pine beetle infested lodgepole pine check trees Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Brood at time treated sections were sprayed								Brood at time other sections were examined							
	Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.		Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	
12.7	46	3	232	—	283	3.3	85.8		—	3	10	129	142	5.0	28.4	
12.3	3	4	184	—	191	3.2	59.7		—	—	1	40	41	3.2	12.8	
12.5	3	—	139	—	142	3.3	43.0		—	—	—	39	39	3.3	11.8	
12.0	10	—	60	—	70	3.1	22.6		—	—	—	68	68	3.1	21.9	
10.9	—	—	9	—	9	1.4	6.4		—	—	—	17	17	2.9	5.9	
12.1	64	7	624	—	695	14.3	48.6		—	3	11	293	307	17.5	17.5	

Percent reduction in brood 64.0

CONCLUSIONS

An analysis of tests conducted with penetrating sprays on mountain-pine-beetle-infested lodgepole pine indicated a number of formulae not only gave satisfactory control but are cheaper than those now in use.

Formula 1 is apparently equally effective and three cents cheaper than the one used at Grand Teton Park in 1940. In addition it seems even more concentrated than is necessary to give effective control, and further reductions in the more expensive ingredients may be possible. However, additional tests are needed to determine if the formula will give equally effective results under more adverse circumstances and the rigorous conditions of a control project.

A saturated solution of naphthalene in xylene mixed with Diesel oil gave sufficiently promising results to warrant further tests. It is possible that xylene may be obtained at a lower cost than orthodichlorobenzene, in which case it might be substituted for the latter as a solvent for naphthalene.

The use of a wetting agent to increase the effectiveness of a low-concentration spray seems to have been successful with Formula 3. However, less wetting agent may prove just as effective, as only part of it was dissolved in the oil in this experiment. If small quantities of wetting agents make it possible to use lower concentrations of the lethal agent, still further reductions in cost may be obtained. Further experiments both with and without wetting agents are suggested.

Insufficient mortality resulted from the tests with pentachlorphenol to warrant further consideration of that chemical.

Further tests with dichlorethyl ether in Diesel oil are suggested because of the excellent results obtained in both the 1939 and 1940 tests. The lowest effective concentrations of dichlorethyl ether in oil do not seem to have been reached and further experiments with weaker mixtures are suggested. If wholesale prices reveal a comparatively low cost for this formula, it may be found as economical as those now in use.

Orthonitrodiphenol also offers a possibility as a lethal control medium in mixture with the Diesel oil. Results were quite satisfactory in the tests made and should be duplicated.

In general the tests conducted in 1940 yielded information concerning certain formulae which seem to equal in effectiveness and may prove more economical than those now accepted for general control.

TESTS OF NONCOMMERCIAL FORMULAE IN WHITEBARK PINE

Experimental treatment of mountain-pine-beetle-infested whitebark pine with noncommercial formulae was conducted at Dunraven Pass near Mt. Washburn in Yellowstone Park. Trees treated were at an elevation of about 9000 feet, on north and west exposures with slopes ranging from 20 to 45 degrees. Stand composition was chiefly whitebark pine in which there were from 10 to 25 percent lodgepole pine, Engelmann spruce, and alpine fir. Most of the treated trees were on well-shaded sites in the midst of a moderately dense stand. Ten log sections and four trees infested with the mountain pine beetle were treated with a mixture of 3 parts Diesel oil to 1 part by volume of a saturated solution of naphthalene flakes in orthodichlorobenzene. Brood subjected to the effect of the sprays included both early and advanced stages of development, the former in trees attacked in 1940 and the latter in those attacked in 1940. Before the 30-inch log sections and the trees were sprayed, counts were made of brood in order to reject material with insufficient infestation.

Spray was applied to the sections or to one side of the trees until the bark glistened with the liquid and drip started. Sprayed sections were placed on platforms off the ground and shaded with branches to prevent sun-killing of the brood. After being sprayed on July 24 the treated material was left until September 13, when examinations were

Table 1, part A – Mountain pine beetle infested whitebark pine treated with formula I (1) – Mt. Washburn – 1940

Living brood in trees attacked in 1939

Estimated brood at time of treating						Surviving brood seven weeks after treating						
Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft. (2)
2	6	10	18	4.0	4.5	—	—	—	2	2	6.2	.3
2	54	5	63	3.2	19.7	—	—	—	9	9	4.7	1.9
5	35	13	56	3.4	16.5	—	—	—	7	7	4.7	1.5
1	15	—	16	3.4	4.7	—	—	—	6	6	5.1	1.2
20	7	—	43	2.8	16.6	—	—	—	8	8	4.3	1.9
20	15	—	46	2.8	16.4	—	—	—	5	5	4.3	1.2
50	132	28	242	19.6	12.3				37	37	29.3	1.3
1	6	—	8	.5	16.0	—	—	—	—	—	.5	—
51	138	28	250	20.1	12.44	—	—	—	37	37	29.8	1.24
with reductions due to emergence												
ections prior to treating					11.04							.44

Percent of reduction obtained as indicated by above averages = 96

Diesel oil ..... 3 parts (by volume)
Saturated solution of naphthalene in ortho-dichlorobenzene at 50° F. (3 lb. per gallon) ... 1 part

Includes emergence which had occurred prior to treatment

As some emergence had occurred prior to treating in the two trees from which the first four sections were taken, a figure representing the amount of this pre-treatment emergence per unit of area was deducted from the final emergence figure noted seven weeks after treating. Although such procedure is subject to some error, it seemed the best solution to the problem of securing a better measure of the effectiveness of the spray. Following this deduction the average emergence for the six sections and one tree was only .44 per square feet and the decrease in living brood about 96 percent. The above figures indicate excellent control by this formula against mountain pine beetle brood in advanced stages of development. Even without the above allowances for pre-treatment emergence the indicated control may be considered satisfactory.

Control of brood in the earlier stages of development was even better than with the later stages when amount of reduction is considered. On the basis of survival per unit of area it is not so good, but it must be pointed out that surviving insects were still immature and consequently would be exposed to the spray for a much longer time than those more nearly mature. Under such conditions further reduction of surviving brood could be expected, so the ultimate mortality figure will probably compare favorably with that obtained against brood in advanced stages of development.

Data from check trees and logs at the end of part B of table 1

Table 1, part B

Living brood in trees attacked in 1940

Estimated brood at time of treating						Surviving brood seven weeks after treating						
Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.
—	—	—	233	1.0	233	3	—	—	—	3	1.4	2.1
—	—	—	215	.5	430	5	—	—	—	5	1.2	4.2
—	—	—	251	.5	502	3	—	—	—	3	1.9	1.6
—	—	—	232	.5	464	—	—	—	—	—	1.1	—
—	—	—	931	2.5	372.8	11	—	—	—	11	5.6	2.0
and small larvae when treated						—	—	—	—	—	.5	—
"	"	"	"	"		—	—	—	—	—	.5	—
"	"	"	"	"		—	—	—	—	—	.5	—
Average survival from sections and trees												1.6
Percent reduction as indicated from sections						99.5						
" " " " " trees						100.0						

CHECK SECTIONS AND TREES - LIVING BROOD

7-23 to 29-1940						9-13 to 19-1940						
and small larvae						495	7	1	—	503	1.6	314.4
"	"	"				299	6	—	—	305	1.2	254.2
"	"	"				121	5	5	—	137	.5	274.0
"	"	"				14	1	—	—	15	.5	30.0
"	"	"				15	4	42	—	61	.5	122.0
"	"	"				4	—	3	—	7	.5	14.0
						948	26	54	—	1,028	4.5	214.2

In a second experiment involving eight sections and five trees, results obtained were not significantly different. The data are presented in table 2 and again we find the trees and sections from trees containing advanced stages of development showing an indicated smaller decrease in brood than similar material containing brood in earlier stages of development. However, the differences are too small to be considered significant, all material having shown satisfactory reduction of brood. In spite of a reduction in the lethal dosage in Formula II, the results showed no significant difference to that of Formula I, which would seem to indicate that the dosage of lethal material is higher than necessary. If such is the case, Formula II, which is the cheaper, could be used with no sacrifice in effectiveness. The same procedure as in table 1, in reducing the final emergence figure, has been made of data from the first three sections and one tree, in which emergence had occurred before treating.

Table 2, part A - Mountain pine beetle infested whitebark pine treated with formula II (1) - Mt. Washburn - 1940

Living brood in trees attacked in 1939

Diameter of Logs	Estimated brood at time of treating: Lar.	Pap.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	Surviving brood seven weeks after treating: Lar.	Pap.	N.A.	NAEH	Total	Sq. ft. of area examined	No per sq. ft.
14.3	4	1	16	9	30	3.7	8.1	—	—	—	—	—	1.9	—
12.7	2	1	68	5	76	3.3	23.0	—	—	—	14	14	5.0	2.8
11.0	—	1	24	1	26	1.4	18.6	—	—	—	9	9	4.3	2.1
11.0	16	20	7	—	43	2.8	15.4	—	—	—	8	8	4.3	1.9
Totals and averages	22	23	115	15	175	11.2	15.6	—	—	—	31	31	15.5	2.0
Trees														
31.0	96	4	9	—	109	1.0	109	—	—	—	—	—	.5	—
18.0			1	2	3	.5	6	—	—	—	—	—	.5	—
11.0	—	1	8	—	9	1.0	9	—	—	—	—	—	.5	—
Totals and averages	96	5	18	2	121	2.5	48.4	—	—	—	—	—	1.5	—
Grand totals and averages	118	28	133	17	296	13.7	21.6	—	—	—	31	31	17.0	1.8

Averages with reduction due to emergence from 3 sections and 1 tree, prior to treating: 19.58: .53 per sq.ft.

Percent of reduction obtained as indicated by above averages : 97.0

(1) Diesel oil ..... 4 parts
Saturated solution of naphthalene in orthodichlorobenzene at 50° F. (3 lb. per gallon) ... 1 part

Table 2, part B

Living brood in trees attacked in 1940

Diameter of Logs	Estimated brood at time of treating: Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No per sq. ft.	Surviving brood seven weeks after treating: Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.
10.5	276	—	—	—	276	1.0	276	—	—	—	—	—	1.4	—
12.0	251	—	—	—	251	.5	502	—	—	—	—	—	1.6	—
15.0	201	—	—	—	201	1.0	201	8	—	—	—	8	2.0	4.0
9.6	287	—	—	—	287	.5	574	1	—	—	—	1	1.3	.8
Totals and averages	1,015	—	—	—	1,015	3.0	338.3	9	—	—	—	9	6.3	1.43
Trees														
18.0	Eggs and small larvae					.5	?	1	—	—	—	1	1.0	1.0
11.0	"	"	"	"		.5	?	2	—	—	—	2	1.0	2.0
Totals and Averages	"	"	"	"		1.0	?	3	—	—	—	3	2.0	1.5
Grand totals and averages	1,015	—	—	—	1,015	4.0	338.3	12	—	—	—	12	8.3	1.45

Percent of reduction obtained as indicated by above averages 99.5

CONCLUSIONS

The outstanding result of these two experiments in whitebark pine is the excellent control secured, which shows that the use of penetrating sprays is feasible in whitebark pine against the mountain pine beetle in both advanced and early stages of brood development. The excellent results obtained seem to warrant a test of the method on a large scale.

TESTS TO DETERMINE REPELLENT AND CONTROL EFFECTIVENESS OF COMMERCIAL FORMULAE MANUFACTURED BY THE DOW CHEMICAL COMPANY 1940

INTRODUCTION

In the spring of 1940 three formulae manufactured by the Dow Chemical Company were sent by authorization of the Washington office of the Bureau of Entomology and Plant Quarantine to the Coeur d'Alene Forest Insect Laboratory to be tested for their effectiveness in repelling and controlling the mountain pine beetle. These formulae were (1) para-chloro-phenoxy-ethoxy-ethyl chloride (K-655), (2) para-tertiary-butyl-phenoxy ethanol (K-58), and (3) dichlordiphenyloxidae (2-X), which will be referred to in the rest of this report as K-655, K-58 and 2-X.

MATERIALS AND METHODS

In all tests of these formulae 1 part by volume of each of the above chemicals was mixed with 3 parts kerosene. Materials treated consisted of 30-inch log sections of lodgepole and whitebark pine supplemented by standing infested trees, all infested with the mountain pine beetle.

Log sections and trees were sprayed until the bark surface glistened with the unabsorbed oil and dripping was ready to start, thus assuring thorough saturation. Unsprayed sections were placed among these

One-half the circumference of the basal five feet of trees was sprayed and the other half left unsprayed to serve as a check on the treatment.

EXPERIMENTS

Tests Against Advanced Stages of Brood Development in Lodgepole Pine With Formula K-655

On June 25 and 26 three lots each of five 30-inch sections of lodgepole pine at Grand Teton Park were sprayed with the three formulae. To supplement the data from the logs, three lots of five trees each were sprayed with the same formulae on July 8. Both the trees and the log sections were examined in early August, the individual data from the sections being given in the following tables.

Table 1 - Mountain pine beetle infested lodgepole pine treated with Formula L-655 - Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of Logs	Estimated brood at time of treating								Estimated brood six weeks after treating							
	Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.		Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	
9.9	5	4	31	—	40	1.3	30.8		—	—	—	20	20	2.7	7.4	
14.6	1	4	101	—	106	1.9	55.8		—	—	—	7	7	4.0	1.8	
14.0	1	3	27	—	31	1.8	17.2		—	—	—	9	9	4.0	2.2	
15.3	6	11	189	—	206	2.0	103.0		—	—	—	1	1	2.8	.4	
15.3	2	9	41	—	52	2.0	26.0		—	—	—	12	12	2.5	4.8	
13.8	15	31	389	—	435	9.0	48.3		—	—	—	49	49	16.0	3.1	
Percent reduction in brood																94

Data from Untreated Sections

	On June 26								On August 3							
12.1	64	7	624	—	695	14.3	48.6		—	3	11	293	307	17.5	17.5	

Inspection of the data in the preceding table reveals considerable variation in the breed at the time of treating and in the survival after treating. Some survival occurred in all sections, being high in two and comparatively low in the other three but averaging too high per square foot to be considered as satisfactory control.

With Formula 2-X

Percentage of reduction was practically as great with this formula as with K-655, but the number surviving per square foot was even higher, thus placing its effectiveness in an even less favorable position than with formula K-655.

Table 2 - Mountain pine beetle infested lodgepole pine treated with Formula 2-X - Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating					Sq. ft. of area examined	No. per sq. ft.	Estimated brood six weeks after treating					Sq. ft. of area examined	No. per sq. ft.
	Lar.	Pup.	W.A.	NAEH	Total			Lar.	Pup.	W.A.	NAEH	Total		
12.5	2	3	36	—	41	1.6	25.6	—	—	—	4	4	3.0	1.3
12.8	63	21	77	—	161	1.6	97.5	—	—	1	6	7	4.0	1.8
14.5	14	8	131	—	153	1.9	80.5	4	6	2	28	40	4.1	9.8
14.0	9	30	188	—	227	1.8	126.1	—	—	4	29	33	4.0	8.2
11.1	12	1	17	—	30	1.5	20.7	—	—	1	11	12	3.2	3.8
13.0	100	63	449	—	612	8.4	72.9	4	6	8	78	96	18.3	5.2

Percent reduction in brood 93

Data from Untreated Sections

	On June 26							On August 3						
12.1	64	7	624	—	695	14.3	48.6	—	3	11	293	307	17.5	17.5

With Formula K-56

Results with Formula K-56 were not satisfactory. The brood reduction noted was almost exactly the same as that in untreated trees, which would indicate the spray had no lethal effect whatever.

The data are given in table 3.

Table 3 - Mountain pine beetle infested lodgepole pine treated with Formula K-58 - Grand Teton Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating: Lar.	Pup.	N.A.	HAHH	Total	Sq. ft. of area examined	No. per sq. ft.	Estimated brood six weeks after treating: Lar.	Pup.	N.A.	HAHH	Total	Sq. ft. of area examined	No. per sq. ft.
12.2	2	1	27	—	30	1.6	18.7	—	—	4	12	16	3.4	4.7
12.7	—	9	40	—	49	1.7	29.7	4	2	5	47	58	3.7	15.7
13.4	—	5	63	—	68	1.8	38.9	—	—	6	64	70	3.7	18.9
12.5	1	—	85	—	86	1.6	52.1	—	—	1	33	34	3.4	10.0
9.9	10	11	126	—	147	1.3	113.0	—	—	2	119	121	2.8	43.2
12.1	13	26	341	—	380	8.0	48.9	4	2	18	275	299	17.0	17.6

Percent reduction in brood 64

Data from Untreated Sections

	On June 26							On August 3						
12.1	64	7	624	—	695	14.3	48.6	—	3	11	293	307	17.5	17.5

Extensive examinations were made of 14 trees treated with the same three chemicals to determine if any difference in control effectiveness might result from spraying sections of logs rather than trees. The data are given in the following summarization.

Table 4 - Data from extensive examination of mountain pine beetle infested lodgepole pine - Grand Teton Park - 1940

TREES TREATED WITH

K-655		2-X		K-58	
Tree No.	Percent reduction in brood	Tree No.	Percent reduction in brood	Tree No.	Percent reduction in brood
1	75	5	95	10	60
2	98	6	90	11	50
3	98	7	95	12	50
4	99	8	95	13	90
--	--	9	95	14	90
Average	92.5		94		68

The data presented in table 4 are from trees that were attacked in the same year as those from which the sections were taken. The variability of the results in individual trees is again brought out in the data in table 4.

The general agreement of the average reduction noted in table 4 with that from the sections that were intensively examined serves to further indicate that the latter is representative of conditions.

Repellent and Control Effect Against Young Brood in Lodgepole Pine

To test the repellent and control effect of the formulae, three lots of five sections each of lodgepole pine in the initial stages of attack by the mountain pine beetle were treated on August 1 in the same manner as the sections sprayed in June. Three unsprayed sections were placed with each sprayed lot of five logs. To supplement the above tests one-half the circumference of the base of trees in the same initial stages of attack was treated, two each with K-655 and K-58 and three with 2-X. Trees were selected that showed initial stages of attack, because presence of the latter indicated the trees were desirable host material and eliminated the problem of chance immunity if unattacked trees had been selected.

Prior to treatment, all sections and trees were carefully examined and all new attacks marked, in order that any attacks subsequent to treatment could be easily identified as such.

From a few preliminary examinations it was found that, due to the comparatively few attacks per unit of area and the high normal mortality of brood in egg and tiny-larval stages of development, a clearer idea of the control effectiveness of the sprays was obtainable by extensive examinations of large areas than by intensive brood counts on small samples, so the former method was adopted. The observations are summarized in table 5.

Table 5 - Control and repellent effect of Dow Chemicals on mountain pine and secondary bark beetles - Grand Teton Park - 1940

FORMULA K-655

Material treated	Sq.ft. of bark surface examined	Control effect on mountain pine beetle	Attacks after treating by: Mountain pine beetle	Attacks after treating by: Secondary bark beetles
Log sections	3	Complete	None	None
" "	3	None	"	"
" "	2	"	"	"
" "	4	"	"	"
" "	3	"	Few	Many
Totals	15			
Tree (1)	9	Good	2	None
"	6	Light	3	"
Totals	15			

(1) One-half of circumference of basal 5 ft.. of tree treated

UNTREATED CHECK SECTIONS

Log sections	.5	Normal development	None	Many
" "	1.0	" "	"	"
" "	4.0	" "	Few	"
" "	1.0	" "	None	Few
" "	1.0	" "	"	Many
" "	1.5	" "	Many	"
" "	5.0	" "	"	"
" "	6.0	" "	"	Few
" "	6.0	" "	"	"
Totals	26.0			

From the preceding table it is seen that control of the mountain pine beetle by Formula E-655 is unsatisfactory. The green bark probably prevents most of the spray penetrating in sufficient quantities to have any appreciable effect on the brood. However, it does seem to be somewhat repellent to both the mountain pine and secondary bark beetles but it not sufficiently effective in that respect to be considered satisfactory. Observations from untreated check sections are summarized in the second part of the table.

Formula 2-X gave somewhat better but still insufficient control of the mountain pine beetle to be satisfactory. As a repellent it was no more effective than E-655 against the mountain pine beetle but was completely effective against secondary bark beetles. A summary of the data is presented in table 6.

Table 6 - Control and repellent effect of Dow Chemicals on mountain pine and secondary bark beetles - Grand Teton Park - 1940

FORMULA 2-X

Material treated	Sq. ft. of bark surface examined	Control effect on mountain pine beetle	Attacks after treating by Mountain pine beetle	Attacks after treating by Secondary bark beetle
Log sections	7	Light	Few	None
" "	6	"	None	"
" "	1	"	Few	"
" "	6	Very little	None	"
" "	2	" "	Few	"
Totals	22			
Tree(1)	6	Light	Few	None
"	1	"	"	"

(1) One-half of circumference of basal 5 feet of tree treated

Table 7

FORMULA K-56

Log sections	1.5	None	None	1
" "	2.0	"	"	Light
" "	1.5	"	"	None
" "	3.0	"	"	"
" "	2.0	"	Heavy	"

Formula K-58 was the least effective in control of the mountain pine beetle of the three formulae, and gave unsatisfactory results as a repellent against both the mountain pine and secondary bark beetles.

All three formulae affect living cambium, causing spotty discoloration and an apparent drying out of the area affected.

Tests Conducted in Whitebark Pine Mt. Washburn, Yellowstone Park - 1940

This experiment was also divided into two sections, based on brood development at the time of treatment, thus permitting a comparison of effectiveness of the spray formula on brood in both early and advanced stages of the mountain pine beetle.

Both log sections and trees were used in the experiment. The data from treatment of trees attacked in 1939 with Formula K-655 are presented in table 8.

Table 5 - Mountain pine beetle infested whitebark pine treated with Formula E-655 - Yellowstone Park - 1940

Living brood in trees attacked in 1939

Diameter of Logs	Estimated brood at time of treating							Brood eight weeks after treating						
	Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.
13.8			13	2	15	1.8	8.3	—	—	—	5	5	5.4	.9
12.7			30	2	32	1.7	18.8	—	—	—	4	4	5.0	.8
13.3	3	1	4	—	8	1.7	4.7	—	—	—	2	2	5.2	.4
10.8	3	6	9	—	18	1.4	12.9	—	—	—	5	5	4.2	1.2
Trees														
19	—	—	1	16	17	.5	34	—	—	—	2	2	.5	4
12	—	—	2	2	4	.5	8	—	—	—	—	—	.5	—
Totals and averages:	6	7	59	22	94	7.6	12.4	—	—	—	18	18	20.8	.87

Less .87 brood per sq. ft. due to emergence prior to treating 11.9 .34

Percent reduction in brood 97

From the preceding table it may be seen that the reduction obtained was excellent. An explanation of the data given is, however, necessary. Shortage of accessible material made it necessary to select some log sections from which a small percent of the brood had already emerged before it was treated. Such emergence occurred from the first two sections and the two trees. It seems justifiable then to reduce the average brood which had emerged eight weeks after treatment by an amount equal to that which had emerged before treatment from the two sections and two trees concerned. As the pre-treatment emergence was about 5.0 per square foot and that after treatment averaged about .97 per square foot, it seems justifiable to eliminate the entire emergence figure after treatment from two sections and two trees, leaving only .34 emergence per average square foot not eliminated, which was from the other two sections which had not shown emergence prior to treating. After an equal elimination of .5 insect per square foot from the pre-treatment figure, we have an average reduction in brood of about 97 per-cent. Treating the data in this manner gives slightly different totals from those shown in the first report. Against the eggs and tiny larvae in trees attacked in 1940, Formula E-655 did not seem to be so effective. This can be expected with the bark still in practically its original green state, through which it is ordinarily considered very difficult for sprays to penetrate.

The data secured are shown in table 9.

Table 9 - Mountain pine beetle infested whitebark pine treated with Formula E-655 - Yellowstone Park - 1940

Living brood in trees attacked in 1940

Estimated brood at time of treating						Estimated brood seven weeks after treating					
Pup.	P.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	Lar. & Pup.	P.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.
—	—	—	157	.5	314	72	—	—	72	1.4	51.4
—	—	—	198	.5	396	39	—	—	39	1.3	30.0
—	—	—	251	.5	502	165	1	—	166	1.7	97.7
—	—	—	232	.5	464	56	—	—	56	1.2	46.7
—	—	—	287	.5	574	25	1	—	26	1.2	21.7
—	—	—	1,125	2.5	450	357	2	—	359	6.8	52.3
Brood on 9/16/40 in untreated portion						Brood on 9/16/40 on treated portion					
—	—	—	33	.5	66	16	—	—	16	.5	32
—	6	—	91	.5	182	12	—	—	12	1.25	9.6
—	6	—	124	1.0	124	28	—	—	28	1.75	16
—	6	—	1,249	3.5	356.9	385	2	—	387	5.55	45.3
% reduction in brood											87.3

Check Sections

—	—	—	251	.5	502	495	7	1	503	1.6	314
—	—	—	232	.5	464	299	6	—	305	1.1	277
—	—	—	483	1.0	483	794	13	1	808	2.7	299

% reduction in brood as indicated by above two sections 38%

The five sections showed an average reduction in brood of about 88.5 percent between the time of treatment and seven weeks later. The two trees, on which no intensive examination was made at the time of treating, showed a difference of about 87 percent in brood on treated and untreated sides on September 16. An average of the data from sections and trees revealed an average reduction in brood on the treatdd side of about 87.3 percent. While such a reduction is good and might be even greater with a longer exposure to the chemical, the survival per unit of area is too high to be able to consider the effect of the formula as satisfactory.

Although the control obtained with Formula K-655 on advanced stages of development was almost complete, it was unsatisfactory against the earlier stages of mountain pine beetle brood and for that reason cannot be considered satisfactory. Normal mortality, judging from the two sections serving as checks, was about 38 percent for brood in early stages of development. Formula 2-X did not give significantly different results from Formula K-655. The data from sections in advanced stages of development are given in table 10.

Table 10 - Mountain pine beetle infested whitebark pine treated with Formula 2-X - Yellowstone Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating: Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	Estimated brood seven weeks after treating: Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.
15.2	4	6	13	2	25	2.0	12.6	—	—	—	9	9	6.0	1.5
13.2	—	—	28	9	37	1.7	21.8	—	—	—	13	13	5.2	2.5
13.0	—	—	6	—	6	1.7	3.5	—	—	—	19	19	5.1	3.7
10.1	3	3	5	—	11	1.3	8.3	—	—	—	5	5	4.0	1.3
Totals and averages:	7	9	52	11	79	6.7	11.8	—	—	—	46	46	20.3	2.3
Trees														
15	—	—	2	7	9	.5	18	—	—	—	4	4	.5	8
11	—	—	2	1	3	.5	6	—	—	—	—	—	.5	—
Totals and averages:	—	—	4	8	12	1.0	12	—	—	—	4	4	1.0	4.0
Grand totals & averages:	7	9	56	19	91	7.7	11.8	—	—	—	50	50	21.3	2.35

After deductions made for early emergence 9.8 .23

Percent reduction in brood 97.5

Making similar deductions to those for table 8 we have a pre-treatment emergence of about 3.0 per square foot to be deducted from emergence noted at the time of treatment of about 2.7, thereby indicating that all the emergence noted in the first three sections and the two trees probably occurred prior to treatment. The remaining emergence would only amount to about .23 insect per square foot and indicates that the reduction in brood had been about 97.5 percent.

In table 11 the data for the effect of Formula 2-X on brood from trees attacked in 1940 are given.

Table 11 - Mountain pine beetle infested whitebark pine treated with Formula 2-X - Yellowstone Park - 1940

Living brood in trees attacked in 1940

Diameter of logs	Estimated brood at time of treating: Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	Estimated brood seven weeks after treating: Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.
12.2	97	—	—	—	97	.5	194	69	—	—	—	69	1.6	43.1
9.3	174	—	—	—	174	.5	348	45	—	—	—	45	1.2	36.9
12.6	251	—	—	—	251	.5	502	58	—	—	—	58	1.6	35.1
10.1	232	—	—	—	232	.5	464	34	—	—	—	34	1.3	25.8
8.6	287	—	—	—	287	.5	574	131	—	—	—	131	1.1	116.4
Totals and averages	1,041	—	—	—	1,041	2.5	416.4	337	—	—	—	337	6.8	49.6
Trees														
13	77	—	—	—	77	.5	154	85	1	—	—	26	.5	52
13	70	6	1	—	77	.5	154	44	—	—	—	44	.5	88
Totals and averages	147	6	1	—	154	1.0	154	69	1	—	—	70	1.0	70
Grand totals & averages	1,188	6	1	—	1,195	3.5	341.4	406	1	—	—	407	7.8	52.2

Percent reduction in brood 85

It is to be seen that although a decided reduction in brood resulted from treatment with this spray the survival is still too high and would probably remain so even had there been a longer exposure with considerably more mortality between treatment and examination.

The unsatisfactory results in treating brood in the early stages of development with Formula 2-X would make its general use in whitebark pine unsatisfactory.

Formula K-58 proved the least effective of the three formulae tested against the mountain pine beetle in whitebark pine. The data from tests made against late stages of development are given in table 12.

Table 12 - Mountain pine beetle infested whitebark pine treated with Formula 1-56 - Yellowstone Park - 1940

Living brood in trees attacked in 1939

Diameter of logs	Estimated brood at time of treating								Estimated brood seven weeks after treating							
	Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.		Lar.	Pup.	N.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	
13.6	2	3	11	—	16	1.8	8.9		—	—	—		30	5.3	5.7	
13.5	2	3	22	10	37	1.7	21.3		—	—	1	24	25	5.2	4.8	
13.0	—	—	13	2	15	1.7	8.8		—	—	—	29	29	5.1	5.7	
10.4	7	3	16	—	26	1.4	18.6		—	—	—	9	9	4.1	2.2	
Totals and averages:	11	9	62	12	94	6.6	14.2		—	—	1	92	93	19.7	4.7	
Trees																
12	—	—	12	—	12	1.0	12		—	—	—	2	2	.5	4	
12	4	2	19	—	25	1.0	25		—	—	—	2	2	.5	4	
Totals and averages:	4	2	31	—	37	2.0	18.5		—	—	—	4	4	1.0	4	
Grand totals & averages:	15	11	93	12	131	8.6	15.2		—	—	1	96	97	20.7	4.1	

Averages following deductions due to pre-treating emergence	13.8	3.0
Percent reduction in brood		78.5

From the data in the preceding table it is seen that reduction in brood by the use of spray K-58 averaged about 67 percent. One tree included in this data in the earlier report has upon further consideration been included in the data in table 13. As that tree had a very heavy brood, its removal has decidedly reduced the average brood both before and after treating.

Again we find the pre-treatment emergence in some of the sections requiring a reduction from the totals of brood before and after treatment in order to properly evaluate the effectiveness of the formula. This reduction, from the data of the first three sections, increases the indicated effectiveness of the formula to 78.5 percent, which, however, cannot be considered as satisfactory control.

Against brood in the early stages of development the formula also gave unsatisfactory control. The data are given in table 13.

Table 13 - Mountain pine beetle infested whitebark pine treated with Formula L-58 - Yellowstone Park - 1940

Living brood in trees attacked in 1940

Diameter of logs	Estimated brood at time of treating							Estimated brood seven weeks after treating						
	Lar.	Pup.	W.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.	Lar.	Pup.	W.A.	NAEH	Total	Sq. ft. of area examined	No. per sq. ft.
11.5	120	—	—	—	120	.5	240	122	—	—	—	122	1.5	81.3
9.6	144	—	—	—	144	.5	288	109	—	—	—	109	1.3	86.8
12.3	251	—	—	—	251	.5	502	170	—	—	—	170	1.6	106.2
9.4	232	—	—	—	232	.5	464	41	1	—	—	42	1.2	34.1
8.8	287	—	—	—	287	.5	574	89	—	—	—	89	1.2	77.3
Totals and averages	1,034	—	—	—	1,034	2.5	413.6	531	1	—	—	532	6.8	78.8
Trees														
11	Eggs and tiny larvae at time of treatment							18	—	—	—	18	.5	36
16	"	"	"	"	"	"	"	96	—	—	—	96	.5	192
Totals and averages								114	—	—	—	114	1.0	228
Grand totals & averages	1,034	—	—	—	1,034	2.5	413.6	645	1	—	—	646	7.8	85.9

Percent reduction in brood 79

From the data in table 13 it is seen that a very numerous brood was greatly reduced but the survival was still too high to consider the formula as giving satisfactory control.

A surprising feature of the action of this formula was that it gave no better control on advanced stages of development than on early stages. There is a slight possibility that sample variation may be responsible, but the large amount of area covered should prevent a large difference from that source.

CONCLUSIONS

Treatment with the three Dow Chemicals against mountain pine beetle brood in the advanced stages of development caused heavy mortality with K-655 and 2-X, but still left too many survivors per square foot of bark surface. Formula K-58 gave decidedly unsatisfactory results. Against brood from recent attacks in lodgepole pine, results were unsatisfactory because of erratic control as well as too much survival.

As repellents these formulae were also unsatisfactory against attacks of the mountain pine beetle. Formulae K-655 and 2-X were most repellent but insufficiently so to warrant their use for that purpose. Repellent effect was somewhat greater against secondary bark beetles, Ips sp., Pityogenes knechteli, Pityophthorus burkei and others, with formula 2-X fully repellent.

Against brood of the mountain pine beetle in whitebark pine formulae K-655 and 2-X gave excellent control, but formula K-58 did not give acceptable results. Brood in trees recently attacked by the mountain pine beetle was unsufficiently controlled by the formulae, with formula K-58 again the least effective.

In general it may be said that the formulae tested can not be recommended because the conditions under which they are effective are too limited.

SUMMARY

Three formulae of the Dow Chemical Company were tested for effectiveness of control against advanced and early stages of development of the mountain pine beetle in lodgepole and whitebark pine.

Under only one condition were two of the three (Formulae K-655 and 2-X) found to give satisfactory control and that was against brood in advanced stages of development in whitebark pine.

As repellents of the mountain pine beetle none were effective, but formula 2-X prevented attack of secondary bark beetles.

These formulae cannot be recommended for control of the mountain pine beetle because the conditions under which they are effective are too limited.

GENERAL SUMMARY

Tests of spray formulae for the control of the mountain pine beetle in lodgepole and whitebark pine reveal certain formulae to be highly effective and cheaper than those now in use. If duplicate and more rigorous tests of the more promising formulae yield equally good results they can supplant those now in use.

An important phase of experiments conducted in 1940 was the determination that penetrating sprays may be used in both lodgepole and whitebark pine. Control in the latter species proved to be less of a problem than was expected when the experiments were begun.

The three commercial formulae tested were not sufficiently effective to warrant recommending their use. Only against brood in the advanced stages of development in whitebark were two of the three formulae effective. As repellents they were ineffective against the mountain pine beetle, but one prevented attack of secondary insects.